DESIGN OF KSTAR MACHINE CONTROL SYSTEM

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Abstract

The Korea Superconducting Tokamak Advanced Research (KSTAR) device, which aims for the steady state operation, requires an advanced control system. It has to be able to maneuver the plasma during discharge. The design features of the KSTAR control system are to adopt two-layer structures, which consist of the web-based wide area network (WAN) for open layer and EPICS based closed layer, to use the distributed database system, and to construct an integrated plasma control system. The VME backbone interfaces various subsystems, but the synchronous timing system is provided separately. Basic data acquisition system of KSTAR, which is a single VME crate with CPU, is a contact point as well as a controller unit for each diagnostic or facility control module. Main network and sub-networks are connected by a gigabit backbone. For outside clients, ISDN and ATM 622Mbps systems will be provided. The KSTAR control system, which controls multi-variables and mixed time scales, utilizes the modern digital technology and the modular approach.

1 INTRODUCTION

After 3 years of design work, the construction of KSTAR tokamak started from 1997 and will end by 2003. The mission of the KSTAR project [1] is to develop a steady-state capable advanced superconducting tokamak to establish the scientific and technological bases for an attractive fusion reactor as a future energy source. Thus, a set of objectives has been established to extend the present stability and performance boundaries of tokamak operations through the active control of profiles and transport. Key issues are to explore methods to achieve steady state operation for tokamak fusion reactors using non-inductive current drive, and to integrate the optimized plasma performance and continuous operations as a step toward an attractive tokamak fusion reactor. In order to meet the mission and objectives of KSTAR, key design features are fully superconducting magnets, long pulse operation capability, flexible pressure and current profile control, flexible plasma shape and position control, and advanced profile and control diagnostics. The control and data system of KSTAR functions to supervise the KSTAR tokamak system operation, to control the plasma discharges, to provide data acquisition and database systems, and to interface and network remotely as well as locally.

2 STRUCTURE OF THE KSTAR CONTROL SYSTEM

A heterogeneous and distributed structure of the control system for KSTAR with its elements is shown in Figure 1. At the top level of the KSTAR control system, the supervisory control system acts as the management system of the tokamak experiment. The machine (tokamak) control system (MCS) plays with sensors and actuators to control the KSTAR itself, and the plasma control system (PCS) can control various properties of the plasma inside the KSTAR. Also, there are the timing system to provide synchronous trigger and timing signals to various components and diagnostic instrument, and the interlocking and safety system to protect human and equipment from hazardous situations. There will be many diagnostics instruments to measure and analyze the properties of the plasma, and they will be controlled individually by corresponding teams. The control and monitor system of auxiliary facilities such as the helium factory will be controlled by its local systems.

The MCS as shown in Figure 2 provides basic and continuous services for test, technical operations without plasma, and preparations of discharges. It stands by the cryogenic system, which manages many sub-systems. The MCS is supervised by a supervisor controller that also serves as a central operator console for inputs and the visualization of technical quantities. During the KSTAR operation, the MCS will allow the PCS to directly set PCS' command values after configuring the actuators. The supervisor of MCS waits for all subsystems to become available again and sends a technical permission message and global parameters to the supervisory control system between discharges.

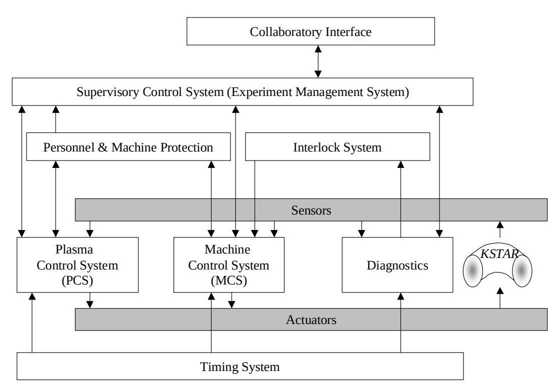

Figure 1: Overview of KSTAR Control System.

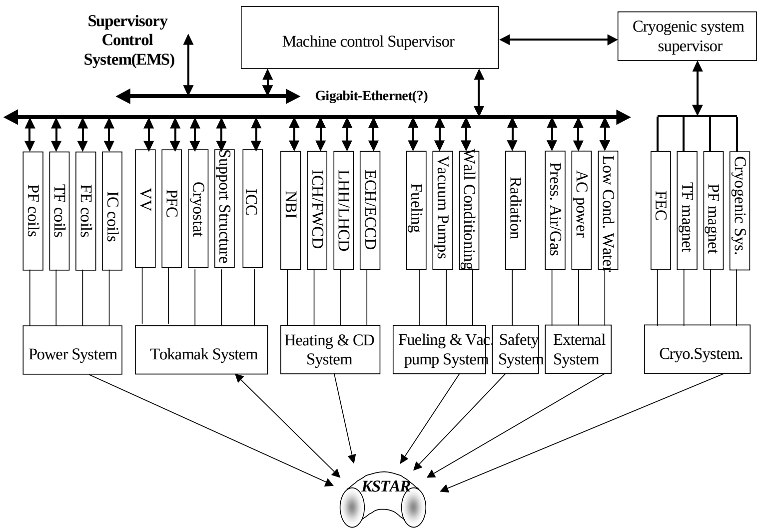

Figure 2: KSTAR Machine Control System.

The real-time PCS will function the plasma control to execute the experimentalist's intentions about the evolution of a discharge and monitors the states of the plasma and the control system. It controls the equilibrium of elongated and diverted plasma using internal control (IC) coils and poloidal (PF) coils through the plasma position and shape controller. The plasma performance controller and the tokamak simulation controller are responsible for the feedback control of the plasma density, the divertor neutral particle flux density, the impurity gas puff, wave-plasma interactions for plasma temperature and current density with information about an equilibrium from the plasma position and the shape controller. An embedded system using object-oriented analysis methods for the fast calculation, flexibility, and scalability is being pursued for the first time in tokamak researches instead of using the remote CPU.

The PCS must directly access actuators provided by the MCS during the discharge. The supervisor controller performs a general time-zero reset for all controller computers with the timing system at the beginning of every discharge. It synchronizes all controllers for a coherent execution of the discharge program. It also collects plasma and technical amplitude signals and state messages from diagnostics, controllers in the PCS and a supervisor controller of the MCS.

The timing system is to guarantee a common absolute time-base throughout PCS, MCS, and all diagnostics with a central clock and time-zero command. In addition, the system is used to distribute the real-time event information. A pulse generator and the time base from the global position system (GPS) will be used to follow the abrupt changes during the discharge.

The tasks of the protection system are to establish priorities and to distribute alarms detected by MCS, PCS, and other technical devices. Thus, the participating controllers and devices are able to perform fast and appropriate counter-actions.

The supervisory control system, i.e., the experiment management system (EMS) is the software platform, which integrates the distributed machine control, the discharge control, the timing system, and the protection systems. The tasks of the EMS are to provide exchange of information between all underlying systems, and to provide the knowledge on available operation functions, the timing constraints, and the operational procedures for automated plant operations. The EMS offers services to initialize subsystems, to link the physical discharge program with the technical settings from the MCS, and to load it into the PCS. The EMS checks that MCS and PCS are ready. Also, it checks the protection system and starts the discharge execution under the control of PCS. After the discharge is done, the control is handed back from PCS to EMS.

Diagnostics in KSTAR provide the information about the plasma into the PCS to control plasma in real-time. The shape, position, and plasma controllers in PCS need inputs from diagnostics to identify the current states of the plasma and to activate actuators such as PF power, IC power, heating and CD, fuel and impurity puffing, and the pumping.

3 NETWORK SYSTEM

The lower limit of network speed has to be about 2~3 Mbps dedicated to each end user for the multimedia communication and the international collaboration. These systems have to provide a high network speed between functional zones of KSTAR building. The network access type will be designed by considering each stage of the KSTAR project. The network is based on the mixed systems of 622MBps-ATM and Gigabit-Ethernet. In order to provide the high network speed between function groups and between zones in the KSTAR building, the star topology is adopted with the FDDI (fiber distributed data interface) dual line structure.

4 DATA ACQUISITION SYSTEM

The KSTAR data acquisition system (DAS) will provide a high-speed data acquisition, a high-speed migration from DAS to the working space (or domain) for data analysis, and a high-speed data manipulation between shots.

A window-NT or UNIX server will be used for the data acquisition server. However, during shots, it will be the web server, which allows many clients to access the data by web based GUI. The hard disk array RAID, which is based on the optical fiber, is considered for the data

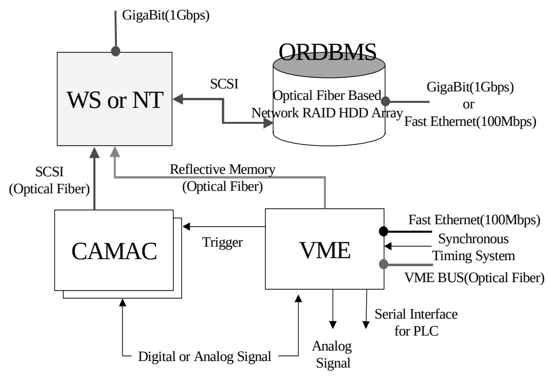

Figure 3: KSTAR Data Acquisition System.

storage. After a shot, collected data will be migrated to the domain for data analysis, which plays roles of the permanent storage system as well as the reference data storage system at the main control room. As a consequence, RAID will be empty after a shot. Operators at the main control room can see the experimental data of the previous shot via a local reference storage system, which will provide manuals and auto-selection mode for operators. The basic concept block diagram of DAS is plotted in Figure 3. The DAS consists of the data acquisition digitizer (CAMAC, VME, VXI, PLC, etc.), the data transfer extender (optical extender of RS232/RS422, GPIB, VME Bus, etc.), the data acquisition server (window-NT, UNIX workstation, etc.), and the data storage system (optical and SCSI based RAID, magnetic optical disk array, etc.).

The system for the data access will be constructed for the open layer and the closed layer. The open layer means that all clients can access the data through a web based GUI using their password. This layer contains the physical experimental data after shots for clients such as domestic and international collaborators. The data in this layer will be located at the open network of KSTAR. Other experimental data are considered to belong to only the closed layer. The closed layer serves the clients for the data communication between the data storage systems and analysis, between the data storage systems and the operators, between one control server and another control server by operation scenarios, and between the data storage systems and the data acquisition systems.

Database systems such as ORDBMS (object-relational data base management system), OODBMS (object-oriented data base management system), and MDSplus, web based GUI, client module, web plug-in for data access, EPICS, and web servers will be utilized for the closed layer. Figure 4 shows the relationship between the open layer and the closed layer.

5 CONCLUSIONS

The long pulse and the steady-state aiming KSTAR tokamak requires the digital method to control device and plasma, which are heterogeneous and distributed systems. The control system of KSTAR will be expanded easily for its frequent upgrade schedule by adopting the modular approach. Open and knowledge based controller platform for PCS allows easy to add new recipes into existing ones and makes feedforward possible. Also, an embedded system using an objective oriented analysis method in PCS for the fast calculation, flexibility, and scalability is considered. Since its superconductors for both toroidal and poloidal coils needs to control so many signals in cryogenic system, KSTAR has the separate supervisory system for cryogenics in MCS. In order to enhance the reliability of networks, the star topology with the dual line structure will be conceived.

Even though the design work for the KSTAR project was started from 1995, the control system design was started from the beginning of 1999. Within the remaining period of time (till year 2003), there will be an intensive work to accomplish the KSTAR control system with KBSI staff and engineers from domestic companies who have various experiences including the construction of the Pohang Light Source (PLS) control system.

ACKNOWLEDGEMENT

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REFERENCES

[1] G.S. Lee, S.M. Hwang, J. Kim, *et al.*, will be appeared in Nuclear Fusion (1999).

[2] G. Raupp, O. Gruber, A. Kallenbach, *et al.*, Fusion Technology **32**, 444 (1997).

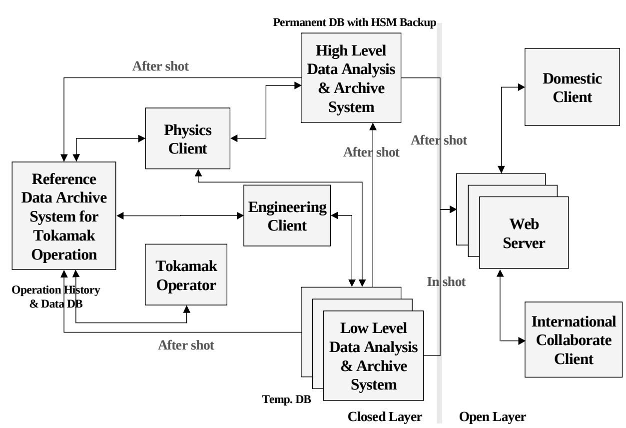

Figure 4: Data Flow Diagram of the DAS.